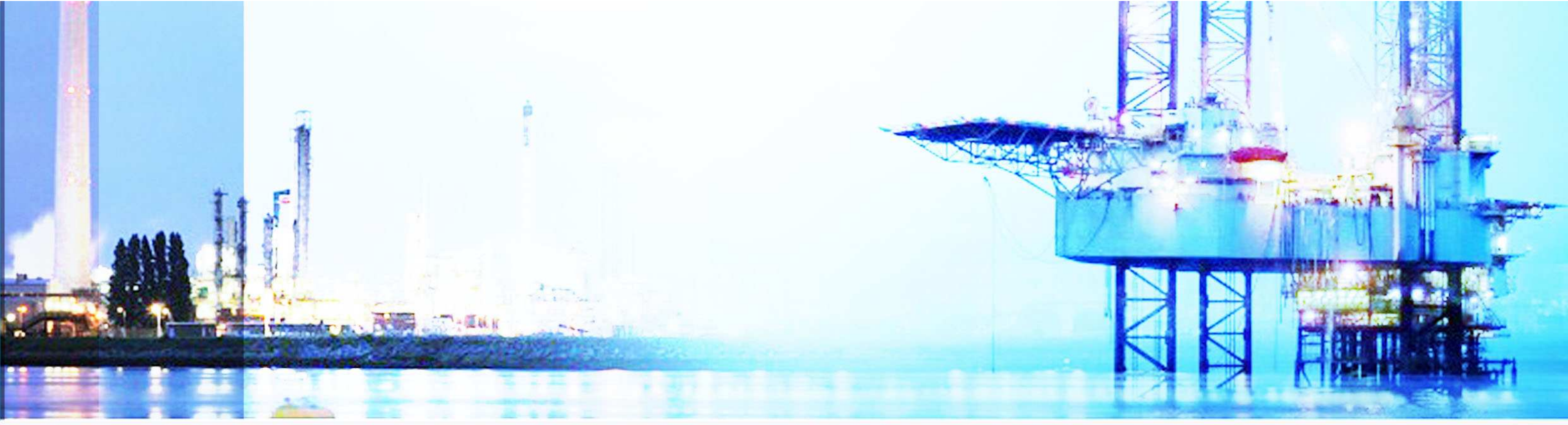

Vol.5, March.2014 ISSN 2354-7065

Journal of
Ocean, Mechanical and Aerospace
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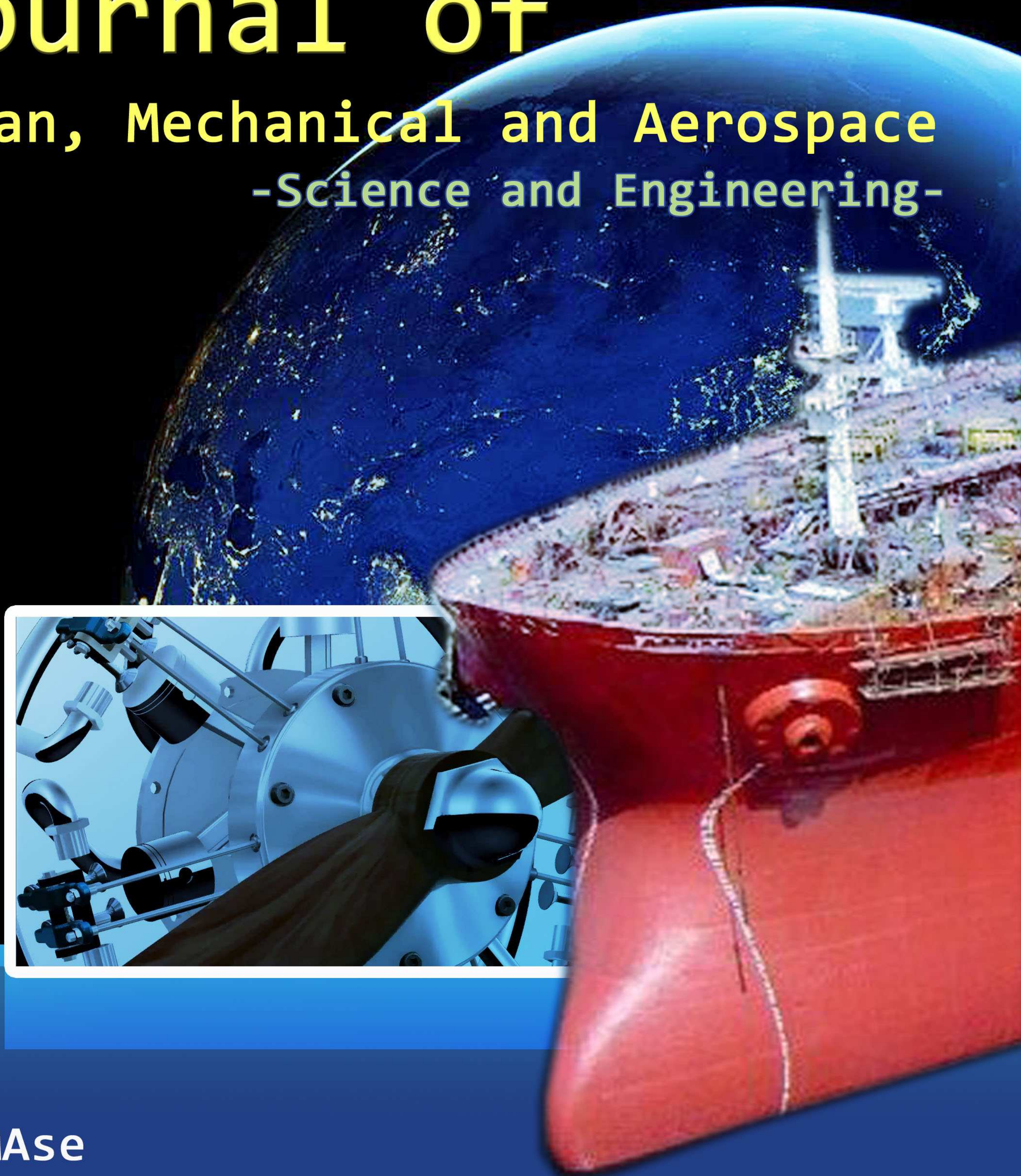

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Journal of Ocean, Mechanical and Aerospace
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Vol.5: March 2014

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Published in Indonesia.

JOMAse

ISOMAse,
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INDONESIA
http://www.isomase.org/

Printed in Indonesia.

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Preliminary Design of Archimedean Screw Turbine Prototype for Remote Area Power Supply

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Paper History

Received: 15-March-2014
Received in revised form: 18-March-2014
Accepted: 19-March-2014

ABSTRACT

This paper is aimed to design a prototype of screw turbine for power generation. Using principles of velocity vector, the governing equations have been identified for an ideal case of force acting on blade. The paper also describes the conception of a screw turbine rotor for remote area electricity production. The research is done by calculating based on theoretical way and compared with experimental results. Output power can be generated by this small size of turbine is 0.236 watt theoretically and 0.098 watt experimentally. Various losses in the system are discussed, which is also demonstrated that the experimental power outputs and theoretical predictions has a discrepancy. However, it has a great potential to be used for remote area to generated power by using low head water source as this research is developed.

KEY WORDS: *Screw Turbine; Low Head; Blade Screw; Power; Remote Area.*

1.0 INTRODUCTION

Energy crisis around the world encourage researcher to pay attention in founding another sources of green energy these days. A lot of research has been conducted by using natural energy sources such as solar, wind, wave and water. According to sources of energy from water to run a turbine, there is a rapid change of technology in using such turbine which suitable for definite kind of flow river, much of them are used for high head (differences) to produce electricity. Meanwhile, Archimedean hydro technology which had a very long history in the world [1], with various machines and mechanism, gears, pumps, various mills driven by water wheels etc. [2]. The Roman engineer Vitruvius gave a detailed and informative description of the construction of an Archimedes screw in his “De Architectura” [3]. During the last years, the inverse use of the Archimedean screw, as a kind of inverse screw pump-turbine, is under discussion within the hydropower scientific community [4-7]. Then it was started to use as Archimedean screw turbine with very low head differences of less than 2-3 metres in several years, so can be used in small river. The renaissance talking place actually throughout the world in the promotion and construction of renewable energy low-head small hydro plants valorises Archimedean screw turbines [8-10]. Such hydropower plants were installed during the last decade in Central Europe by several industrial companies, which are based on the inversion of the energy flow in their pump operation and turning the old screw pumps into new Archimedean turbines [1]. However, low head hydropower plants are developing very slowly, despite the fact that recent Archimedean screws are new type of turbines mainly in Greece but also in other countries throughout the globe [1].

Furthermore, in the rapid-change of technology these days, there is an environmental issue for saving fish and other biota on water while using water as a source of energy. As seen in several developed countries, there is a ban to dam a river that can disturb its ecosystem. There should be a consideration of how to safe them while building hydropower electricity system. Installation of Archimedean screw turbines is unlikely to have an impact on the quantity and quality of spawning and juvenille coarse fish habitat available in some areas [11, 12, 13].

In addition, Indonesia has a lot of big and small river. Especially in Bengkulu province, it has many small rivers with lower head, and this province does not have sufficient electricity. So Archimedean screw turbine one of appropriate technology can be applied there.

An interest in micro-hydropower turbine has grown year by year. The feasibility of micro-hydropower by using axial flow turbine was examined. However, this kind of turbine has several weaknesses such as its need of high head and its lack of environmentally friendly causing fish cannot pass through that turbine blade. Because of these, another kind of turbines- Archimedean screw turbine- has attracted much attention and its practical application has been accelerated in developed countries, meeting with demand for improvements in using natural sources of energy. Due to this situation, the applications of hydropower turbine to generate electricity has been actively researched. In current practice of hydropower turbine, there is a rapid introduction of lower head kinds of turbines.

Therefore, any kind of axial flow turbines like Kaplan and Pelton have also been energetically studied. However, not only because this type of turbine is not applicable to any river on that area due to its need of high head, but also because there is no chance for fish to move along the river due to the water in the dam has to flow through the turbine. Therefore, a turbine that can eliminate such a delicate problem is highly desirable.

This paper will focus mainly in making a prototype and experimentation of Archimedean screw turbine under the micro-hydro range for low head applications. Simple manufacturing methods using locally available material will be presented. The performance of the test unit will be explored and evaluated as well as identify potential areas for improvement.

2.0 PREVIOUS WORK

Some researches already done about Archimedean screw. At first, Archimedean screw is used as a pump to raise water for irrigation and drainage [8]. Recently, researches concerning to this area are Archimedean screw has also found a new application operating in reverse as an energy converter for low head differences [17], measurements of the Archimedean as an energy converter showed the effect of inflow water level to diameter, and gave efficiencies between 79 and 84%, making this an interesting alternative for turbines in low head hydropower applications [5, 14, 17, 18], the power is generated by the hydrostatic pressure difference and the horizontal screw velocity [5,16] and blade screw.

Bengkulu province has a lot of small river with low head so that this kind of turbine can be applied. This province is still lack of electricity particularly in many remote areas. Therefore, research about Archimedean screw turbine must be done.

3.0 BASIC DESIGN

Water weight is generally assumed enclosed by the screw's blades drives the screw [14, 18]. If no losses are assumed, all potential energy contained in the flow can be extracted giving such a machine the theoretical maximum efficiency of 100%. However, most of the water weight in the Archimedean screw rests on the trough, which does not move. Power is generated by force and velocity, and since the velocity vector of the rotating screw acts tangentially to the screw, only a small part of the water weight enclosed in the screw (the part which is resting on the inclined outer section of the blade) contributes to energy conversion. Unlike the water in the cells of an overshot water wheel, weight force direction of the complete water mass coincides with the downward direction of the cell movement. The contribution of the weight force is therefore neglected.

A screw has a head difference h, a total length L and m turns of the helix with a horizontal distance l in contact with the water.

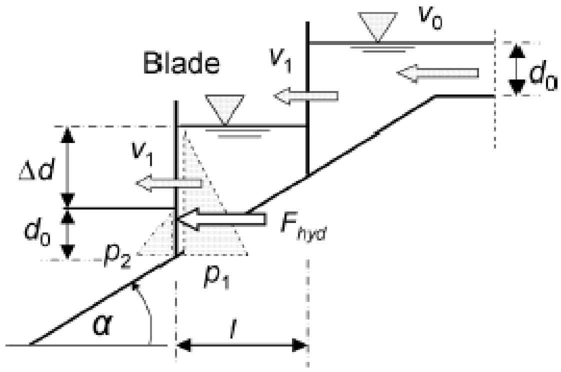

Figure1 Force acting on individual screw blade [5]

If volume and diameter of inlet pipe are known, flow rate (Q), entry velocity (v_0) and flow velocity (v_1) are :

$$Q = \frac{P}{\rho \,.\, g \,.\, H} = A \times V \tag{1}$$

$$v_0 = \frac{Q}{A} \tag{2}$$

The differential water levels of each blade generate a hydraulic force (F_{hyd}). While this force rotate screw with speed v_1, it can generate a power :

$$P_s = F_{hyd} \times v_1 \tag{3}$$

Trough angle (α) is relative to horizontal, a distance (l) between two individual blades makes the water depth increases by :

$$\Delta d = l \tan\alpha = \left({}^{L}/_{m}\right) tan\,\alpha = \frac{h}{m} \tag{4}$$

So, hydrostatic force is then determined to

$$F_{hyd} = \frac{(d_0+\Delta d)^2}{2}\rho.g \tag{5}$$

Water speed in screw (flow velocity) is

$$v_1 = \frac{d_0}{d_0+\Delta d} v_0 \tag{6}$$

Power of one blade (P_{blade}) produce by multiplication of force and velocity. If there are m blades, so total power (P) will be increased. Therefore, available hydraulic power (P_{hyd}) is

$$P_{hyd} = \rho.g.Q.h = \rho.g.d_0.v_0.m.\Delta d \tag{7}$$

$$P_{blade} = P_{hyd} \times v_1 \tag{8}$$

$$P = m \times P_{blade} \tag{9}$$

While n = d0/Δd then theoritical efficiency η_{th} becomes

$$\eta_{th} = \frac{P}{P_{hyd}} = \frac{2n+1}{2n+2} \quad (10)$$

4.0 GOVERNING EQUATIONS

By using formulas theoretical calculation, results can be determined and the values are : flow rate (Q) is 0.00019 m3/s, inlet area (A) is 0.00114 m2, inlet speed (v_0) is 0.167 m/s, water depth increased (Δd) is 0.05 m while inlet water depth (d_0) is 0.00126 m , hydraulic force (F_{hyd}) is 6.4 N, speed of water in screw blade (flow velocity, v_1) is 0.0041 m/s. All of these values will end to get power of screw turbine (P), 0.236 Watt respectively and theoretical efficiency (η_{th}) 50 % is gotten.

5.0 EXPERIMENTAL SET UP

Screw turbine prototype is made by using locally available materials. PVC pipe with 4 in diameter is used as duct (trough), aluminum is used as screw blade and joined by using rivetted. Turbine is installed with elevation of through (α) 45^0. Two reservoirs and two pumps is used to keep flow rate constant (figure 2 and 3).

Figure 2 Prototype of Srew turbine

Figure 3 Inlet reservoir

To make sure that electricity is really generated by this device, not only some led lamps is installed on bicycle generator is on, but also measured by using multimeter to show how much current and voltage are generated. (figure 4, 5 and 6).

Figure 4 Led lamps

Figure 5 Measuring voltage

Figure 6 Measuring current

6.0 PERFORMANCE CHARACTERISTICS

By using flow rate of water (Q) 19 ml/s (0.00019 m^3/s) with inlet speed (v_0) 0,167 m/s, and also with measurement of rotation with tachometer get 232 rpm on turbine pulley and 560 rpm on generator pulley this turbine can generate power 0.098 watt, which consist of 33.1 mA current and voltage 2.97 volt. Comparing this power with power from theorytical prediction, efficiency of this turbine is 41%. This experiment has lower efficiency than theoritical prediction (50%).

This turbine is built with locally simple materials and installed in easy way without paying attention in precision, particularly in position of generator, excentricity between generator and turbine shaft, and also tension (tight) of belt and pulley diameter. Because of lack of measurement device, torque of turbine cannot be measured. Results of this experiment is promising because better installing of this turbine should increase its performance. Furthermore, different angle of trough and blade might be taken effect on turbine performance.

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7.0 CONCLUSION

Valuable information about the performance characteristics of screw turbine was collected through the experiments.

Screw turbine is built succesfully with locally simple material and this turbine can generate power 0.098 watt with 41% efficiency. By considering equipments and measurement tools that used, this result is promising to be continued. It should need more research to do before this turbine used in remote area.

8.0 FUTURE WORK

To get optimum parameter design, it needs to be done more research in other angle of trough and blade, and also addition on number of blade and influenced of length of blade screw.

ACKNOWLEDGEMENTS

The author would like to thank DIPA Universitas Bengkulu for funding under grant agreement no. 258/UN30.10/PL/2013. The Author also wishes to thank Afdhal Kurniawan M., Ahmad Fauzan S., Putra Bismantolo and Hendra Haryadi for the experimental support.

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ISSN: 2354-7065